



The implications of high bed occupancy rates on readmission rates in England: A longitudinal study



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ABSTRACT

Hospital bed occupancy rates in the English National Health Service have risen to levels considered clinically unsafe. This study assesses the association of increased bed occupancy with changes in the percentage of overnight patients discharged from hospital on a given day, and their subsequent 30-day readmission rate. Longitudinal panel data methods are used to analyse secondary care records ($n = 4,193,590$) for 136 non-specialist Trusts between April 2014 and February 2016. The average bed occupancy rate across the study period was 90.4%. A 1% increase in bed occupancy was associated with a 0.49% rise in the discharge rate, and a 0.011% increase in the 30-day readmission rate for discharged patients. These associations became more pronounced once bed occupancy exceeded 95%. When bed occupancy rates were high, hospitals discharged a greater proportion of their patients. Those were mostly younger and less clinically complex, suggesting that hospitals are successfully prioritising early discharge amongst least vulnerable patients. However, while increased bed occupancy was not associated with a substantial increase in overall 30-day readmission rates, the relationship was more pronounced in older and sicker patients, indicating possible links with short-fallings in discharge processes.

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1. Introduction

The percentage of hospital beds that are occupied at any one point in time has been increasing in England and has risen over the past decade from an average of 84.5% in 2006/07 to 91.4% in the period from January to March 2017 [1]. The trend may be due in part to a policy to move care into community settings, which has encouraged the closure of hospital beds without achieving corresponding reductions in the number of hospital admissions [2]. In fact, the number of admissions has increased from 12.7 million in 2005/06 to 16.2 million in 2015/16 [3], while the bed stock has decreased from 300,000 beds in 1987/88 to 131,000 in 2015/16 [1,4]. This means that England has now one of the lowest rates of hospital beds per population (i.e., the number of beds per 1000 population decreased from 6.3 beds in 1987 to 2.3 beds in 2016)

[1,5], and bed occupancy rates are particularly high, though Israel, Ireland and Norway also have rates exceeding 90% [6].

Clinical leadership has expressed concern about rises in bed occupancy rates and how they might affect the ability of hospital teams to deliver high quality care [7]. There are particular concerns that high bed occupancy rates might lead to an increased likelihood of adverse events [8], challenges in securing the resources needed to diagnose and treat patients [9], and problems with planning for the discharge of larger numbers of patients [10]. Particularly, individual patients might be discharged sooner when bed occupancy rates are high [11], perhaps because care teams face additional pressures at these times to reduce bed occupancy to more manageable levels. It is unknown, yet plausible that in some cases patients are being discharged before adequate transitional or post-discharge care support is put into place, and this might carry a risk to patient care and could materialise in a hospital readmission [12]. High bed occupancy rates might also have implications for patient safety, as they have been linked to an increased likelihood of hospital-associated infections such as methicillin-resistant staphylococcus and clostridium difficile [13–15]. Despite the salience of the issue

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to resource-stretched hospitals, very little research has examined the implications of high bed occupancy rates for hospital processes and quality of care. One notable study examined data from a 420-bed emergency hospital in Sweden [16], and found that patients who were discharged from hospital on days with high bed occupancy rates had an appreciably higher risk of being readmitted within 30 days following discharge (odds ratio: 1.11; 95% CI, 1.01 to 1.22). The authors attributed the increased readmission risk to a premature discharge of patients, supporting fears raised by clinical leadership in England. However, it is unknown whether this phenomenon is unique to that one hospital in Sweden, or whether there is a more general link between high bed occupancy and readmissions, instigated through an impact on the quality of discharge processes.

If readmission rates were indeed raised at times of high bed occupancy, this would require careful attention. Avoidable readmissions may be undesirable for patients and services alike, and they have been associated with other markers of care quality along the patient pathway, including in-hospital care [17], transitional care services [18–20] and post-discharge support [21,22]. They are also linked to downstream pressures on hospital beds, raising the possibility that efforts to free up beds for the management of short-term pressures might be storing up problems for the future. Since there has been few published research in this area, the aim of this study was to first assess whether rises in hospital bed occupancy associates with changes in hospital discharge rates, thus testing a hypothesis raised by clinicians and patient representatives in recent years. And secondly, to assess whether those patients that are discharged when bed occupancy is high are more likely to return to hospital within 30-days, providing evidence for potentially adverse effects on the quality of discharge processes. This was done by examining data for all acute hospitals in England, measuring bed occupancy for each hospital on a daily basis over a two-year period.

2. Method

2.1. Study sample

We studied all acute NHS trusts in England (i.e., healthcare providers that typically manage several hospital sites). We included all patients recorded as inpatients from these trusts when aged 18 or over, regardless of admission method (i.e., including both planned elective and emergency admissions, with the latter including direct referrals from A&E departments) between 1 April 2014 and 29 February 2016. A two-year study period was chosen based on the availability of data and relevance of this issue to current policy debates, including the concerns raised during the past Winter periods [7,23]. We focussed on patients staying overnight in hospital, and thus excluded patients who were admitted and discharged on the same day. We also excluded patients discharged in March 2016, to allow calculating 30-day readmissions within the constraints of the data.

Data were sourced from the Hospital Episode Statistics (HES) database, a national administrative dataset containing records for patients receiving health care services by the NHS in England. The data spanned April 2014 to March 2016, and included information on patient demographics, diagnoses, and admission and discharge dates. Patients experiencing multiple admissions during the observation period were treated as separate inpatient spells (admissions) in the analysis. Patients with incomplete records on information required for risk-adjustment were excluded.

2.2. Bed occupancy rates

We calculated the bed occupancy rate for each trust and each day between 1 April 2014 and 29 February 2016, as the number of inpatients present at midnight divided by the total number of beds in the trust. We focussed on the midnight bed occupancy rate because HES includes only the date, but not the time, of admission and discharge. The number of inpatients present at midnight can be calculated based on a consideration of the dates alone. The number of beds was obtained from publicly reported data [1], which are updated every three months as the average of the daily number of beds and include beds for general and acute care, maternity, learning disability and mental health services, but exclude beds for critical care [24].

2.3. Hospital discharge rates

We calculated the hospital discharge rate for each trust and each day across the study period as the proportion of patients who were discharged. Our focus was restricted to people recorded as inpatients at midnight the previous night. The hospital discharge rates were risk-adjusted for the characteristics of patients in hospital at midnight, including age on admission, sex, ethnicity, comorbidities measured by the Charlson Index that uses data from the indexed hospital admission and a look-back period of one year [25,26], socioeconomic deprivation score (Index of Multiple Deprivation based on 2010 census data of small geographic areas of patients residence, each containing on average 1500 residents) [27], and elapsed length of stay (i.e., the number of nights from admission to the date in question). Length of stay was entered into the risk-adjustment process due to its association with an increased risk of suffering an adverse event for every extra day spent in hospital [28], which could impact on the patients recovery time. Moreover, in the absence of any adequate measures of severity in the HES data, length of stay acts as a proxy as used in other studies reporting on risk-adjusted readmission rates [29,30]. By not accounting for length of stay, we would discount the fact that patients who have been in hospital for longer due to their clinical complexity could be wrongly identified as discharge-ready and would therefore be more likely to be discharged when bed occupancy rates are high. Conditional logistic regression models were fitted to the patient-level data and used to predict the hospital discharge rate for each trust and day. The observed hospital discharge rate was then divided by the predicted hospital discharge rate from the conditional logistic regression models to indicate whether the trust over or underperformed relative to the level expected. We then multiplied this ratio by the average hospital discharge rate across all trusts for that day to calculate the risk-adjusted discharge rate. This method is analogous to the risk-adjustment methodology used for the public reporting of readmission rates in England, but also other indicators such as patient reported outcome measures [31,32].

2.4. Readmission rates

As defined by policy-makers in England, we identified a hospital readmission from HES as any all-cause, unplanned emergency admission occurring within 30-days of discharge [33]. We used method of admission codes ('21' – via A&E; '22' – via general practitioner; '23' – via Bed Bureau; '24' – via consultant outpatient clinic; '28' – other means, such as arriving via A&E of another provider; '2A' – A&E of another provider where the patient had not been admitted; '2B' – transfer from another provider in an emergency) to identify emergency readmission from the patient-level HES file. Readmission rates were calculated for each trust and each day between 1 April 2014 and 29 February 2016, as the proportion of patients discharged on that day who were subsequently readmitted as an

emergency within 30-days. We restricted the calculation of the readmission rates to patients who had been inpatients at midnight the previous night, and thus ensured consistency with the populations included in our other metrics.

The readmission rates were risk-adjusted using the same methodology that was used for the discharge rates. We fitted conditional logistic regression models to patient-level data, adjusting for the same variables as used for the adjustment of hospital discharge rates. The choice of variables used for the risk-adjustment of readmission rates was guided by the literature [29,30]. To calculate risk-adjusted readmission rates, for each trust and day we divided the observed readmission rate by the predicted readmission rate, and then multiplied this ratio by the average readmission rate observed across all trusts for that day.

2.5. Statistical analysis

We first assessed the relationship between bed occupancy and the risk-adjusted discharge rates, and then the relationship between bed occupancy and the risk-adjusted readmission rates. In each case, we used linear panel data models [37], which make use of the longitudinal nature of the data, with observations across 136 trusts and up to 699 time points (i.e., days). The models included trust-level fixed effects, which control for factors that are specific to the trust, yet which remained constant over time (such as the characteristics of the surrounding area, and teaching hospital status). Based on emerging evidence on the pressures imposed on clinical teams when bed occupancy is high, we tested the hypothesis that higher levels of bed occupancy rates are associated with higher hospital discharge rates, and a subsequently elevated risk for patients to be readmitted due to potentially adverse effects on the quality of the discharge processes. It was possible that the relationship between bed occupancy rates on readmissions becomes stronger when beds are scarce, since pressures on beds become more acute and harder to manage. Therefore, we conducted sensitivity analyses to test for non-linear associations between bed occupancy rates, discharge rates and readmission rates. Dose-response curves were plotted using the overlaid predictions from the original model that included squared terms.

Some trusts lacked complete data, for example because they had not been in existence for the entire study period. We used an unbalanced panel in our main analysis that included each trust regardless of the number of available observations. As a sensitivity analysis, we constructed a strictly balanced panel that was limited to trusts with complete data (i.e., only included trusts that had one observation for every day across the study period).

2.6. Subgroup analyses

Subgroup analyses assessed whether the associations were stronger or weaker in certain patient groups and trusts, since some patients naturally present with more complex needs whose addressing may require better care coordination following hospital discharge. Patients were segmented by age group (i.e., 18 to 35 years; 36 to 50 years; 51 to 65 years; 66 to 80 years; 81 to 90 years; and 91 years or older); the number of comorbidities (i.e., none; 1; 2; 3; 4; 5; and 6 or above); and quintiles of the socioeconomic deprivation score (i.e., patients living in most deprived areas – centile 1, to patients living in least deprived areas – centile 5). In each case, we re-estimated our main model to data for the relevant patient subgroup. We also considered instances where trusts had bed occupancy rates in excess of 94.3% (the upper tertile of the distribution) to examine further the evidence from one Swedish hospital that very high bed occupancy rates lead to greater marginal increases

in readmission rates as a result of poor quality discharge processes [16].

3. Results

3.1. Study sample

Between April 2014 and February 2016, 4,193,590 overnight patients met our inclusion criteria from 136 acute NHS trusts. We excluded 8,462,811 patients who were admitted and discharged on the same day, with 82% accounting for elective day-cases and 18% being emergencies, and a further 2,269,350 patients without complete records for risk-adjustment and being below the age of 18 years. Patients in our study sample were on average 63.6 years of age (Standard Deviation, SD: 4.22 years), with an average Charlson index of 0.98 (SD: 0.22) and an average hospital length of stay of 6.5 days (SD: 2.23). These characteristics changed only marginally over time. Table 1 presents summary statistics on a three-month basis; note that the final observation is limited to the period from 1 January 2016 to 29 February 2016.

3.2. Trends in bed occupancy, observed discharges and observed readmissions

Across the observation period, we found an increase in the bed occupancy rate from 89.7% in April to June 2014 (range 60.9%–100.0%) to 91.8% in January and February 2016 (range 67.7%–100.0%). Similarly, the average percentage of patients discharged per day increased over this time period from 15.0% (range 2.0%–31.0%) to 16.3% (range 3.0%–31.0%), whereas the percentage of patient readmitted within 30 days decreased from 13.3% (range 0.0%–29.0%) to 12.5% (range 0.0%–29.0%).

3.3. Panel data models

We estimated that, for each one-per-cent increase in the overnight bed occupancy rate, the patients who had been in hospital overnight saw their probability of discharge increase by an absolute 0.49 percentage points (95% CI, 0.48%–0.50%). Therefore, not only did the absolute number of discharges increase when a greater number of hospital beds are occupied, but also individual patients were more likely to be discharged.

Patients who were discharged following nights with a high bed occupancy rate were more likely to be readmitted in the subsequent 30-day period. We estimated that each one-per-cent increase in the overnight bed occupancy rate was associated with a 0.011% (95% CI, 0.003%–0.019%) increase in risk-adjusted 30-day readmission risk. Our findings were robust to changes in method to use a panel that comprised only trusts with complete information for each day across the study period (see Appendix A).

3.4. Dose-response curves

Fig. 1 depicts the dose-response curves. The strength of the relationship between discharge rates and bed occupancy diminished as bed occupancy increased. In contrast, readmission rates increased more quickly once bed occupancy exceeded around 80%.

When we re-analysed data for a restricted sample of trusts and days that had a minimum bed occupancy rate of 94.4%, we found that any additional absolute one per cent increase in bed occupancy associated with a 0.50% (95% CI, 0.45%–0.56%) increase in discharge rates, and a 0.04% (95% CI, 0.003%–0.076%) increase in the readmission rates for discharged patients.

Table 1
Descriptive statistics, showing daily outcome variables and variables used for risk-adjustment by NHS Trusts and for eight quarters.

Variables	Quarter 1 Apr '14 to Jun '14 <i>Mean (SD)</i>	Quarter 2 Jul '14 to Sep '14 <i>Mean (SD)</i>	Quarter 3 Oct '14 to Dec '14 <i>Mean (SD)</i>	Quarter 4 Jan '15 to Mar '15 <i>Mean (SD)</i>	Quarter 5 Apr '15 to Jun '15 <i>Mean (SD)</i>	Quarter 6 Jul '15 to Sep '15 <i>Mean (SD)</i>	Quarter 7 Oct '15 to Dec '15 <i>Mean (SD)</i>	Quarter 8 Jan '16 to Feb '16 <i>Mean (SD)</i>
Patient age (years)	63.20 (4.19)	63.06 (4.20)	63.73 (4.33)	64.45 (4.30)	63.61 (4.16)	63.46 (4.11)	64.04 (4.11)	64.20 (4.18)
Female (%)	54.19 (7.36)	54.17 (7.35)	54.15 (7.37)	54.38 (7.14)	54.02 (7.18)	53.90 (7.30)	53.93 (7.23)	54.29 (7.16)
White (%)	92.71 (10.29)	92.97 (10.22)	92.81 (10.38)	93.33 (9.92)	92.70 (10.31)	93.07 (9.68)	93.17 (9.80)	92.71 (10.25)
Black (%)	1.83 (4.34)	1.74 (4.32)	1.83 (4.45)	1.75 (4.33)	1.94 (4.70)	1.78 (4.34)	1.70 (4.24)	1.90 (4.72)
Asian (%)	3.66 (5.65)	3.63 (5.71)	3.66 (5.74)	3.38 (5.44)	3.70 (5.62)	3.49 (5.20)	3.47 (5.34)	3.56 (5.32)
Other (%)	1.63 (3.10)	1.50 (2.81)	1.55 (2.81)	1.38 (2.59)	1.49 (2.56)	1.49 (2.72)	1.49 (2.86)	1.64 (2.96)
Length of stay (in days)	6.41 (2.21)	6.34 (2.15)	6.45 (2.25)	6.82 (2.29)	6.59 (2.20)	6.45 (2.21)	6.47 (2.23)	6.76 (2.33)
Charlson comorbidity index	0.95 (0.23)	0.96 (0.23)	0.98 (0.21)	0.98 (0.20)	0.98 (0.21)	0.99 (0.21)	1.00 (0.22)	1.00 (0.21)
No of patients discharged per day from quintile 1 - IMD score (least deprived)	16.46 (16.89)	16.25 (16.37)	16.56 (16.78)	16.48 (16.64)	16.56 (16.64)	16.50 (16.50)	16.65 (16.89)	16.71 (16.72)
No of patients discharged per day from quintile 2 - IMD score	15.11 (10.52)	14.98 (10.15)	15.21 (10.60)	15.17 (10.30)	15.33 (10/52)	15.23 (10.40)	15.36 (10.56)	15.52 (10.56)
No of patients discharged per day from quintile 3 - IMD score	15.30 (9.39)	15.11 (9.10)	15.32 (9.32)	15.29(9.04)	15.45 (9.24)	15.29 (9.12)	15.65 (9.53)	15.57 (9.25)
No of patients discharged per day from quintile 4 - IMD score	15.66 (9.78)	15.46 (9.53)	15.83 (9.92)	15.67 (9.55)	15.82 (9.80)	15.68 (9.65)	15.96 (9.94)	15.86 (9.68)
No of patients discharged per day from quintile 5 - IMD score (most deprived)	15.77 (12.25)	15.72 (12.06)	15.97 (12.60)	15.85 (12.39)	16.05 (12.86)	15.92 (12.86)	16.23 (13.09)	16.16 (13.05)
Adjusted discharge rate (%)	15.06 (7.59)	15.40 (7.24)	15.00 (7.84)	13.97 (6.46)	14.88 (7.27)	15.58 (7.15)	15.60 (8.07)	16.34 (10.46)
Adjusted 30-day readmission rate (%)	13.35 (5.05)	13.04 (4.95)	12.54 (4.95)	12.08 4.71)	12.89 (4.82)	13.02 (4.86)	13.00 (5.18)	12.53 (4.81)
No. of acute NHS trusts	136	136	135	135	135	135	135	135
No of total available hospital beds	751.10 (352.68)	747.07 (351.80)	767.26 (361.66)	777.92 (362.84)	774.84 (354.16)	760.13 (326.27)	749.77 (311.89)	754.74 (316.35)
No of inpatients at midnight	674.17 (318.07)	668.01 (315.23)	693.57 (328.42)	712.21 (329.17)	701.59 (323.52)	685.10 (303.54)	685.43 (298.48)	694.46 (300.65)
Bed occupancy (%)	89.74 (6.87)	89.45 (6.82)	90.51 (6.71)	91.85 (5.78)	90.58 (6.40)	89.89 (6.76)	91.09 (6.49)	91.82 (5.38)

Note: Analysis restricted to patients meeting study inclusion criteria; We calculated risk-adjusted discharge rates and readmission rates by multiplying the ratio of observed and predicted rates by the respective average rate observed for all trusts.

Table 2

The association between bed occupancy and a) risk-adjusted discharge rate, b) risk-adjusted readmission rate for patient subgroups.

	Discharge rate		Readmission rate	
	Coefficient	95% CI	Coefficient	95% CI
Age group				
18 years–35 years	0.50***	0.48–0.53	–0.06***	–0.08 to –0.04
36 years–50 years	0.53***	0.51–0.55	–0.11***	–0.13 to –0.09
51 years–65 years	0.49***	0.47–0.51	–0.03***	–0.05 to –0.01
66 years–80 years	0.40***	0.39–0.42	0.02***	0.01–0.40
81 years–90 years	0.31***	0.29–0.33	0.09***	0.08–0.11
91 years and over	0.23***	0.20–0.25	0.11***	0.08–0.15
Number of comorbidity				
0	0.48***	0.46–0.49	–0.04***	–0.04 to –0.03
1	0.42***	0.41–0.44	0.02**	0.00–0.04
2	0.33***	0.31–0.35	0.01	–0.01–0.03
3	0.27***	0.24–0.30	0.10***	0.06–0.14
4	0.19***	0.16–0.23	0.11***	0.04–0.17
5	0.07	–0.46 to 0.62	0.13**	0.01–0.24
6 or above	0.27***	0.24–0.29	0.07***	0.02–0.12
Socioeconomic deprivation score				
Quintile 1 (Most deprived)	0.41***	0.38–0.43	0.00	–0.01 to 0.03
Quintile 2	0.42***	0.40–0.44	0.02*	–0.00 to 0.04
Quintile 3	0.42***	0.40–0.44	–0.00	–0.02 to 0.01
Quintile 4	0.41***	0.39–0.43	0.02**	0.01–0.04
Quintile 5 (Least deprived)	0.40***	0.48–0.42	–0.03***	–0.05 to –0.01

Note: *** Indicates that the variable has robust impact on dependent variable at 1% significance level, ** for 5% and * for 10%.

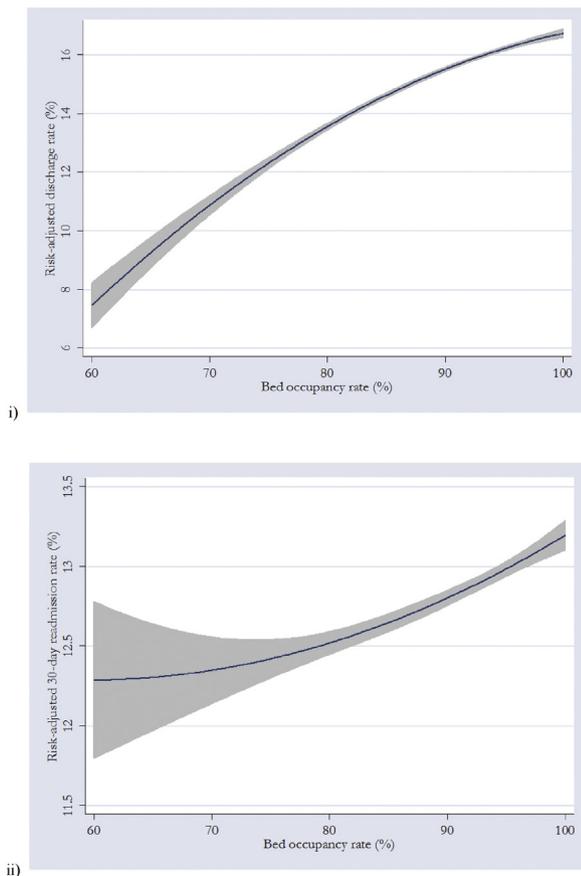


Fig. 1. Dose response curves relating levels of bed occupancy to the risk-adjusted discharge rate (i) and the risk-adjusted readmission rate (ii).

3.5. Subgroup analysis

To estimate which patients are more likely to be discharged when pressures on beds are high, we re-estimated our main model for several patient subgroups – see Table 2. We found that patients

aged between years 18–65 saw greatest increases in the discharge rate when pressures on beds were rising. In fact, years 18–65 (0.50%; CI 95%, 0.48–0.53) present with a 38% higher marginal increase in being discharged compared with patients aged between years 81–90 (0.31%; CI 95%, 0.29–0.33%). We find similar patterns for patients presenting with comorbidities. Patients with no comorbidity (0.48%; CI 95%, 0.46–0.49%), or 1 comorbidity (0.42%; CI 95%, 0.41–0.44) had the highest likelihood for being discharged when bed occupancy rates are high. In comparison, patients with more than 3 comorbidities were only half as likely to be discharged (e.g., coefficient for patients with 4 comorbidities was equal to 0.19; 95% CI, 0.16–0.23) on the same days. We find no significant differences in discharge rates for patients with varying socioeconomic backgrounds.

For the same patient subgroups, we re-estimated our main model to investigate differential impacts of being readmitted, given that readmissions are employed as a measure for the quality of the discharge process. We found that patients who were discharged on days with high bed occupancy rates and aged above 65 years were more likely to be readmitted within 30 days (e.g., coefficient for 81 years to 90 years was equal to 0.09%; CI 95%, 0.08–0.11). Similarly, the larger the number of comorbidities, the more likely it is that the patient was being readmitted when discharged on days with high bed occupancy. While patients with no comorbidity have a slightly reduced risk of readmission (coefficient equal to –0.04%; CI 95%, –0.04 to –0.03) for every 1% increase in bed occupancy rate, estimates for patients who present with 4 comorbidities showed a 0.11% (CI 95%, 0.04–0.17%) increase for every 1% increase in bed occupancy. Similar to the discharge rate, we find no substantial difference in readmission rate by level of socioeconomic deprivation.

4. Discussion

Bed occupancy rates in England have been steadily increasing from 84.5% in 2006/07, to an average of 91.4% in the first three months of 2017 [1], and it is unknown to what extent this is affecting the quality and safety of care provided to patients. We examined data for all acute NHS trusts in England and showed that following nights with a greater proportion of beds occupied, a larger pro-

portion of patients are discharged from hospital. The individual probability of discharge increased by about 0.49% for each additional 1% of beds occupied (95% CI, 0.48%–0.50%). This risk of early discharge was most pronounced in patients who were younger, and with less comorbidity. Therefore, it appears that patients are discharged earlier when beds are full, though the additional discharge risk was lower for older and more complex patients. This could indicate that hospitals are allocating scarce beds to the most vulnerable patients, or that it is more challenging to accelerate the discharges of older patients, for example due to limitations in the availability of post-discharge support in the community.

Concerns have been raised that pressures on beds might adversely affect the quality of care provided, for example because of the inadequate discharge planning or coordination [7]. We found that patients had a higher risk of readmission when they were discharged at times when more beds were occupied, but the increases were small in comparison to the usual 30-day readmission rate of around 12.5% for the average patient who remains in hospital a minimum of one night. For each 1% increase in bed occupancy, the 30-day readmission rate increased by 0.011% (95% CI, 0.003%–0.019%), though the association was more pronounced when the bed occupancy rate reached its highest levels and amongst certain population groups. For example, the association was around four times greater when the bed occupancy rate exceeded 95%, with readmission risk increasing by 0.04% for each percentage point increase in bed occupancy above that level (95% CI, 0.003%–0.076%). The association was also more pronounced for older patients (0.09% increase in readmission risk for patients aged years 81–90 for each additional 1% of beds occupied; CI 95%, 0.08%–0.11%), and those with several comorbidities (0.10% increase or higher; CI 95%, 0.06–0.14). However, even at the highest levels of bed occupancy, the increased readmission risk is unlikely to be clinically significant. Our findings suggest that hospitals are managing the additional pressures on hospital beds by discharging the least vulnerable patients in ways that do not lead to additional readmissions. However, the slight increases in readmissions that we detected might still signal wider impacts on the quality of care, which warrant further investigation. High bed occupancy rates are likely to remain a concern, not only in the NHS, but also across other health systems that are expected to face rises in demand for their services in the future [38].

4.1. Prior research

Previous research using data from one 420-bed emergency hospital in Sweden found that patients discharged on days with high bed occupancy rates were at higher risk of readmission, and the authors attributed this to poor quality discharge processes [16]. The effect size from the study was larger than our findings, equivalent to an absolute increase in the 30-day readmission rate of around 1.3% (95% CI, 0.4%–2.2%) when bed occupancy was between 95% to 100%, compared with under 95%. We found an increase of 0.04% for each percentage increase in bed occupancy above 95%. We cannot be definitive about why the association was smaller in England, but it may be that hospitals are more effectively managing the pressures associated with high bed occupancy rates. Unlike the previous study, we examined the association between high bed occupancy rates and readmission rates across a representative sample of patients nationally, which included patients admitted as an emergency and planned elective. This is the first national study in the area, though other research also explored the relationship between hospital demand and discharge rates, and found that long-stay patients are more likely to be discharged on days of high demand in the Australian health care system [11]. Finally, we note that a study based on one teaching hospital in Canada estab-

lished a link between bed occupancy rates and readmission risk in the intensive care setting [39].

4.2. Strengths and limitations

Bed occupancy rates only capture one aspect of the pressures that exist on care teams, and indeed we measured bed occupancy at midnight when further changes occur during the day. Although the NHS has started to report bed occupancy on a daily basis for the Winter months in 2012 [40], which underlines the assumed relevance to reflect on hospital pressure, the focus on midnight bed occupancy arose as a result of limitations with the hospital administrative data. The data allowed us to measure bed occupancy on a daily basis for all acute NHS trusts across a two-year period. While the numerator for our bed occupancy rate included all patients, we note that the denominator was taken from publicly available information on the number of overnight beds per trust. Since this was only available on a quarterly basis, we were not able to account for some of the ways in which hospitals deal with pressures on beds, such as the temporary extension of bed capacity to deal with peaks in demand. High bed occupancy presents as a significant challenge for the NHS because of the limitations associated with absorbing unexpected increases in the number of patients going to the hospital if beds are filled. However, if bed occupancy is lower, then increases in admission rates are easier to deal with provided the staff are also available.

We measured quality of care using the 30-day hospital readmission rate, which is widely used to assess hospital performance [29,41–44], since readmissions have shown to correlate with quality of care along the patient pathway [20,21,30]. Readmissions are generally undesirable for patients if they can be avoided and represent additional burden for health systems, including downstream pressures on beds and additional costs [43]. However, the small increase in readmission risk detected in this study may not place a notable burden on patients or the health system and it is important to note that the links between readmissions and care quality are not straightforward [45]. For example, some readmissions are clinically appropriate and, on busy days, consultants may adopt a deliberate strategy to discharge patients earlier with instructions to return should conditions worsen. These early discharges might be associated with benefits to patients even if there is an increased readmission risk (e.g., because shorter lengths of stay mean less time in hospital settings that are often psychologically and physiologically straining for patients) [28,46]. Further studies are needed to provide a more granular picture, and these could examine metrics that relate to processes in other parts of the clinical pathway, safety, clinical and patient-focussed outcomes and experience of care [47]. Studies could also investigate patient groups not considered in this paper. For consistency with the calculation of the bed occupancy rates, we restricted our study to patients who remained in hospital overnight, yet pressures on beds might also affect the quality of care delivered to patients who are admitted for a shorter period of time. High bed occupancy rates might also create problems in other parts of the hospital, since for example they have been associated with longer waiting times in emergency departments [48], as well as longer waits for beds [49].

Another consideration regarding the use of readmission rates is that they can be affected by the quality of post-discharge care, which may not be under the control of the hospital, or indeed factors outside the direct control of health systems, such as socioeconomic status [45,50]. Our study design aimed to adjust for these and other factors by using a panel data model, which examined fluctuations in bed occupancy rates over time and tested whether these were associated with contemporaneous changes in readmission rates within the same hospital trusts, instigated through poorer quality of discharge processes. This approach enabled us to account

for one form of endogeneity, the unobserved heterogeneity in the characteristics of trusts provided their relationship with the outcome remained the same across the observation period. We also adjusted for changes in patient demographic and clinical characteristics over time through our risk-adjustment method. Still, there is a residual risk of bias, since pressures on post-discharge services might coincide with pressures on the local hospitals (e.g., if there are sudden adverse changes to weather), and our findings may be affected by changes in care management over time, such as the introduction of ‘discharge-to-assess’ models [51], or trusts investing into additional social care capacity [51,52]. Our method also carries a risk relating to simultaneity in the relationship between bed occupancy rates and discharge rates. However, the study findings offer quantitative support for this relationship previously suggested by clinical leaders and the Parliamentary Ombudsman [7,12].

4.3. Implications

This study provides evidence that high bed occupancy is associated with a small but statistically significant increase in discharge rate and hospital readmissions. We observed that the association between bed occupancy and discharge was most pronounced in younger, less complex patients who are at reduced risk of readmission. Therefore, our findings could suggest that hospitals are largely successfully maintaining quality of care under high bed occupancy for the majority of patients, though there may be implications for other aspects of quality than those considered in this study. Further research is needed so that approaches to address the impact of bed occupancy can be grounded in a deeper understanding of the mechanisms through which problems with care delivery materialise.

If, following further research, it emerges that approaches are needed to address the implications of high bed occupancy rates for quality of care, then there are several strategies that could be taken. One strategy, which has featured heavily in national policy in England for some time, is to try to reduce demand on hospitals by strengthening primary and community care [53]. Many cross-sectional, observational studies have found links between markers of the quality of primary and community care and admission rates [54–56], though it has proven difficult to translate these insights into effective interventions [57–59], with some exceptions [60,61]. Other strategies might focus on improving the flow of patients through hospitals, for example by re-designing processes to ensure that care inputs are available as soon as patients require them, thereby shortening length of stay [62]. Still other approaches might address the quality of the discharge process. Several care models are being developed, including ‘discharge-to-assess’, which involves patients being discharged sooner provided they are medically fit and can be supported with short-term packages to continue their recovery and rehabilitation at home [51]; and deploying trusted assessors to carry out need-assessments for post-discharge support on behalf of all providers along the clinical pathway (i.e., including the discharging trust, local authority and social care) [63]. A final strategy would be to increase hospital capacity, though we note that further reductions to the number of acute hospital beds is a feature of many of the Sustainability and Transformation Plans that were submitted to NHS England in 2016 [64].

4.4. Conclusions

Following nights of high bed occupancy rates, more patients are being discharged with a small increase in the risk of readmission within 30 days. It is possible that additional pressure to release beds on these days is leading to some patients being discharged sooner than usually. No evidence of a marked change in readmission rates

as a result was found, but there might be implications for other dimensions of care quality.

Although there have been fears that high bed occupancy is leading to poorer discharge processes and more patients being readmitted at a later date, these seem to be unfounded based on evidence provided in our study. This might be because hospitals are successfully prioritising early discharge amongst least vulnerable patients.

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Data sharing

The data controller of the data analysed is NHS Digital. Patient-level data is available subject to their information governance requirements.

CRedit authorship contribution statement

Rocco Friebe: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Visualization, Project administration. **Rebecca Fisher:** Writing - review & editing. **Sarah R. Deeny:** Validation, Writing - review & editing. **Tim Gardner:** Writing - review & editing. **Aoife Molloy:** Writing - review & editing. **Adam Steventon:** Methodology, Validation, Writing - review & editing, Supervision, Project administration.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.healthpol.2019.06.006>.

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